OBSERVATION OF OCTET AND DECUPLET HYPERONS IN e^+e^- ANNIHILATION AT 10 GeV CENTRE-OF-MASS ENERGY

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Results on hyperon production are reported for data accumulated at 10 GeV centre-of-mass energy with the ARGUS detector. Signals for both the octet states Λ, Σ^0 and Ξ^- and the decuplet states $\Sigma^{\pm}$ (1385), Ξ^0 (1530) and Ω^- are observed[1] (references to a specific state are to be interpreted as also implying the charge conjugate state), some for the first time in e^+e^- annihilation. Baryon rates from Υ_{dir} (1S) decays are enhanced by a factor of about 3 over the continuum.

Studies of baryon production in hard interactions have recently become of great experimental [1-7] and theoretical [8-14] interest. A better understanding of parton fragmentation is expected to follow from these investigations, since baryons, due to their higher mass, reflect more details of the earlier stages of the fragmentation cascade than the copiously produced mesons. The latter turn out to be predominantly decay products of heavier resonances [15] and therefore reveal only indirectly information on the primary process of parton fragmentation. Baryons with more than 1 strange quark are especially suited to directly study the fragmentation process since they are with high probability primaries and not decay products of a higher mass state.

More detailed questions to be tackled with the present data sample are connected with the proposed mechanisms which allow one to model baryon production:

- phase space break up of colourless clusters which terminate the parton evolution [11-13],
- creation of localized diquarks in a colour field, where spin-1 diquarks are suppressed relative to spin-0 diquarks due to their higher mass [9],
- creation of single quarks in a colour field where nonlocalized quarks may coalesce into a diquark system [10,14].

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The measured production rates of hyperons, with different spin and strangeness content, help to fix the free parameters of these models and may allow one to discriminate between the different descriptions of baryon production in hard interactions.

The data were collected with the ARGUS detector at the DORIS II storage ring at DESY. The centre-of-mass energies ranged from 9.4 to 10.6 GeV. The detector, its trigger and particle identification capabilities, are described in ref. [16]. The event sample used in the analysis corresponds to an integrated luminosity of 21.7 pb^{-1} on the Υ(1S), 36.2 pb^{-1} on the Υ(2S), 59 pb^{-1} on the Υ(4S), and 26.9 pb^{-1} in the nearby continuum.

In this analysis the acceptance of charged particles was defined by cuts on the transverse momentum, $p_T > 60$ MeV/c, and the polar, $|\cos\theta| < 0.92$. For a given charged track, all mass hypotheses were accepted for which the likelihood ratio [17] constructed from the dE/dx and time-of-flight measurements exceeded 5%. Lambdas were selected by a soft cut on the χ^2 of the fit of $p\pi^-$ combinations to secondary vertices. The resulting invariant mass distribution (fig. 1) displays a signal of 27 328 ± 195 entries with low background. The fitted value of the

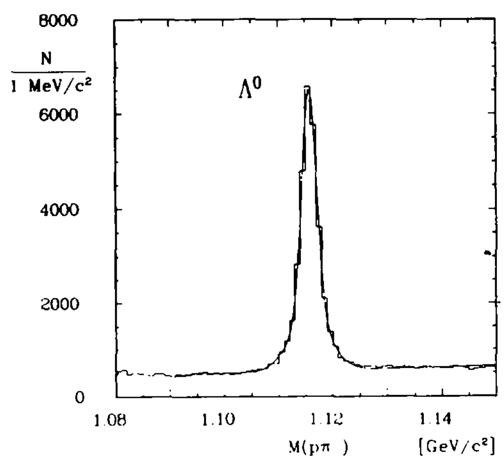

Fig. 1. Measured mass distribution of $p\pi^-$ combinations.

mass, (1115.7 ± 0.2) MeV/c^2, is in good agreement with the world average [18].

Subtracting the continuum and vacuum polarization contributions from the signal on the $\Upsilon(1S)$, we find that the rate of Λ production per event for $\Upsilon_{dir}(1S)$ decays is 2.7 ± 0.4 times that observed in the continuum. The systematic errors from the Λ reconstruction efficiency almost cancel in this ratio. This enhancement of baryon production was first observed by DASP II [1], and is in agreement with recently reported result from CLEO [3].

To reconstruct higher mass hyperons, all Λ candidates lying within 3 standard deviations of the nominal Λ mass, and with momentum greater than 0.2 GeV/c, were subject to a mass constraint fit before being used to form mass combinations. In fig. 2a the invariant mass distribution of $\Lambda\pi^-$ combinations with momentum greater than 0.4 GeV/c is shown. A clear peak of 1885 ± 86 events can be seen at a mass of (1321.4 ± 0.3) MeV/c^2, due to Ξ^- production. The solid line is the result of a fit with a gaussian for the Ξ^- in combination with a relativistic Breit–Wigner for the $\Sigma^-(1385)$ and a background consisting of a phase space component modeled by a polynomial with a square-root threshold behaviour and a correlated reflection component at 1.28 GeV/c^2. The latter arises from $(p\pi_1^-)\pi_2^-$ combinations where π_1^- is a random track but the proton and π_2^- are from a Λ decay. The observed width of the Ξ^-, (3.8 ± 0.5) MeV/c^2, is compatible with the expected mass resolution determined by a Monte Carlo calculation. Again, the production rate for baryons per event from $\Upsilon_{dir}(1S)$ decays is found to be enhanced over the continuum, in the case of the Ξ^- by a factor of 2.9 ± 0.9. Correcting for the detection efficiency of the slow pion and a 13% higher acceptance for the Λ from the Ξ^- decay (due to the long Ξ^- lifetime) we obtain a Ξ^-/Λ ratio of 0.08 ± 0.01 in $\Upsilon_{dir}(1S)$ decays and 0.09 ± 0.02 in the continuum.

In addition to the narrow Ξ^- resonance, a broad structure corresponding to the production of the $\Sigma^-(1385)$ can be observed in fig. 2a. Exploiting the fact that for $\Sigma^-(1385) \to \Lambda\pi^-$ the π^- is prompt, this signal can be enhanced by a soft cut ($\chi^2 < 49$) on the fit of the π^- to the primary vertex. The resulting mass distribution is shown in fig. 2b. A broad peak at a mass of (1386 ± 3.1) MeV/c^2 is observed.

The distribution of $\Lambda\pi^+$ invariant mass (fig. 2c)

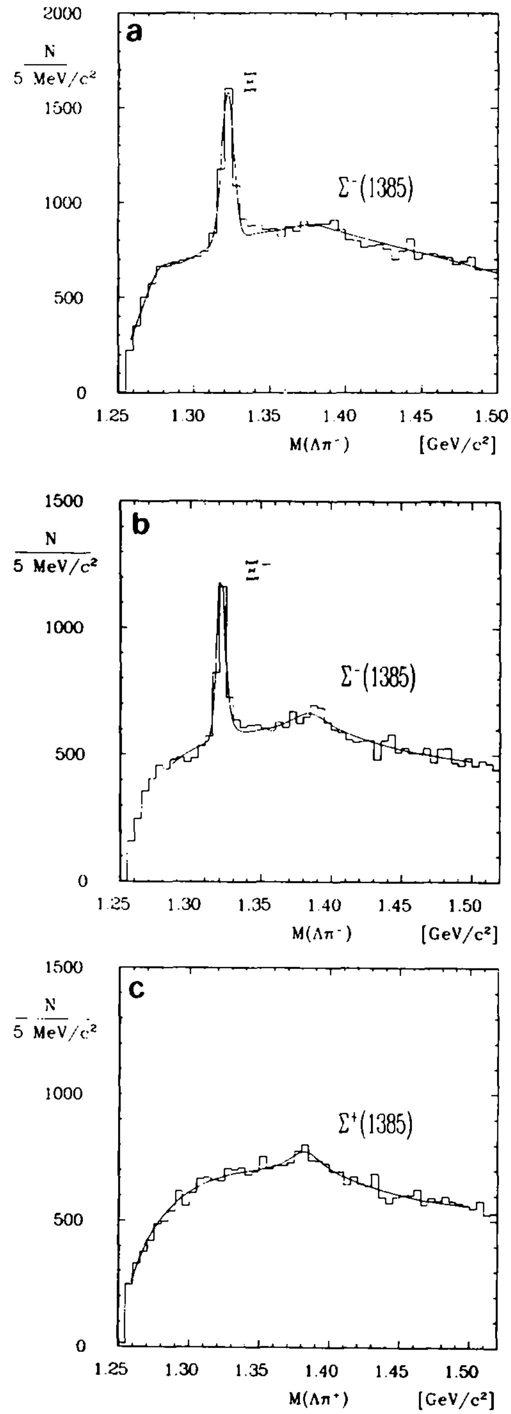

Fig. 2. (a) $\Lambda\pi^-$ mass distribution. The solid line is the sum of a polynomial background plus a gaussian for the Ξ^-. (b) As in (a) with the requirement that $\chi^2 < 49$ for the fit of the π^- to the primary vertex. (c) As in (b), but for $\Lambda\pi^+$ combinations.

shows a broad enhancement at the position of the $\Sigma^+(1385)$. From a fit to the data, using a relativistic p-wave Breit–Wigner of width 40(35) MeV/c^2 for the $\Sigma^-(1385)$ ($\Sigma^+(1385)$) in combination with a polynomial background plus a gaussian for the Ξ^-, we obtain 721 ± 93 (793 ± 101) entries for the $\Sigma^-(1385)$ ($\Sigma^+(1385)$) signal. The fitted relativistic Breit–Wigner was integrated from 1.35 to 1.42 GeV/c^2 to obtain this result. Correcting for efficiency and the missing tail of the Breit–Wigner distribution, we arrive at the following ratios for decuplet-to-octet baryon production:

$$\Sigma^-(1385)/\Lambda = 0.047\pm0.006^{+0.006}_{-0.005}\,,$$

$$\Sigma^+(1385)/\Lambda = 0.052\pm0.007^{+0.006}_{-0.004}\,.$$

The sum of the ratios is well within the limit reported by TASSO [5], but is considerably smaller than the value of 0.32 ± 0.08 obtained by TPC [19].

In fig. 3 the spectrum of $\Xi^-\pi^+$ invariant mass is shown. A peak is observed at the position of the $\Xi^0(1530)$ containing 279 ± 46 events. For this analysis, a Ξ^- candidate was defined as a $\Lambda\pi^-$ combination lying within ±15 MeV/c^2 of the nominal Ξ^- mass, and with momentum greater than 0.4 GeV/c. These candidates were subject to a mass constraint fit before being combined with a π^+ from the primary vertex. The direct rate of $\Xi^0(1530)$ production from $\Upsilon_{dir}(1S)$ decays is found to be a factor 3.3 ± 1.1 times that in the continuum. In drawing this conclusion, we assumed that no $\Upsilon(4S)$ decays to $\Xi^0(1530)$ exist and hence the combined continuum and $\Upsilon(4S)$ data could be used for the continuum subtraction. The ratio of $\Xi^0(1530)$ to Ξ^- was found to be 0.27 ± 0.07 in $\Upsilon_{dir}(1S)$ decays and 0.24 ± 0.08 in the combined $\Upsilon(4S)$ and continuum data. Therefore we conclude that no difference in decuplet-to-octet baryon production on and off resonance exists within our present errors. Our result of this ratio, averaged over all data, of $0.26\pm0.04^{+0.04}_{-0.02}$ is well above the limit of 0.16 at the 90% CL published by CLEO [2].

A search for the Ω^- was made in the ΛK^- mass distribution shown in fig. 4. The observed signal

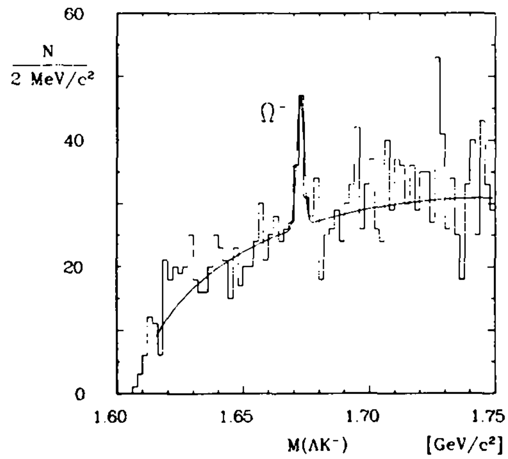

Fig. 4. ΛK^- mass distribution.

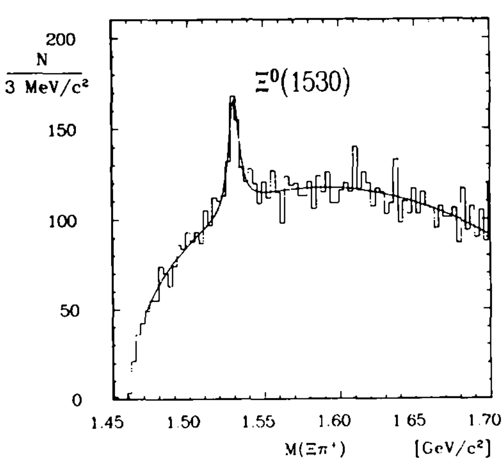

Fig. 3. $\Xi^-\pi^+$ mass distribution.

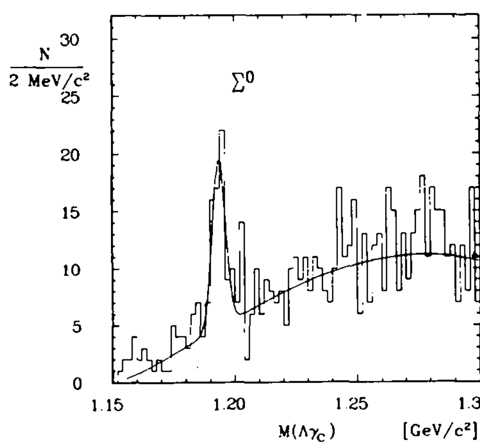

Fig. 5. $\Lambda\gamma$ mass distribution, where γ is a converted photon reconstructed from an e^+e^- pair forming a secondary vertex.

Table 1
Measured ratio of production cross sections, averaged over all data, compared to predictions of the Lund model (version 6.2).

Ratio	Measurement	Popcorn qq	Popcorn ggg	Diquark ggg
Σ^0/Λ	$0.33^{+0.11}_{-0.09}$	0.16	0.20	0.21
Ξ^-/Λ	0.08 ± 0.01	0.07	0.07	0.08
$(\Sigma^+(1385)+\Sigma^-(1385))/\Lambda$	$0.10\pm0.01^{+0.013}_{-0.010}$	0.15	0.19	0.11
$\Xi^0(1530)/\Xi^-$	$0.26\pm0.04^{+0.04}_{-0.02}$	0.20	0.18	0.13
Ω^-/Λ	$(5.4\ \pm1.8\ \pm1.2)\times10^{-3}$	2×10^{-3}	2×10^{-3}	3×10^{-4}
Λ/p	0.32 ± 0.06 [a]	0.36	0.31	0.32
Δ^{++}/p	$<12\%$ (95% CL) [b]	0.11	0.16	0.09

[a] From CLEO [3] on $\Upsilon(1S)$. [b] From TASSO [4].

amounts to 53 ± 16 events at the Ω^- mass. After acceptance correction, this corresponds to a Ω^-/Λ ratio of $(5.4\pm1.8\pm1.2)\times10^{-3}$.

A total of 53 ± 10 events are observed at the position of the Σ^0 mass, if one combines Λ's with converted photons reconstructed from e^+e^- pairs forming secondary vertices [20]. The excellent resolution or the converted photons results in a detectable signal (fig. 5) with an RMS width of only (2.7 ± 0.5) MeV/c^2, despite the fact that the conversion times reconstruction probability is quite small. Correcting for acceptance, a ratio of Σ^0 to Λ production of $0.03^{+0.11}_{-0.09}$ is obtained.

The particle ratios, averaged over all data, are collected in table 1. One can conclude that more than 50% of all observed Λ particles are due to the decay of other strange baryons. This observation underlines the importance of studies which determine the production of high mass states in the fragmentation process.

The Lund fragmentation model [9,10] describes most of the observed features of quark and gluon fragmentation [21,22]. Hence, it is of interest to compare our results with the predictions of this succesful fragmentation model. In table 1, this comparison is made for two different versions of the model. The basis of the point-like diquark model is the production of localized diquarks in the colour field, while the popcorn model assumes the coalescence of singly created quarks into a diquark system. In the popcorn model, the diquarks are not correlated, hence decuplet baryon production is less suppressed. Most of the measured production ratios are reproduced by the model. However, the difference between the ratios $\Sigma^{\pm}(1385)/\Lambda$ and $\Xi^0(1530)/\Xi^-$ is in disagreement with the predicted near equality. This result may indicate that the ratio of the probability for spin-1 and spin-0 diquarks depends on the strangeness content of the diquarks. A measurement of the production rate for Δ resonances will permit a check of this conjecture.

In summary we have observed the production of octet and decuplet hyperons in quark and gluon jets. Hyperon rates from $\Upsilon(1S)$ decays are enhanced by a factor of about 3 over the continuum. More than 50% of the observed Λ particles are produced by decays of heavier hyperons.

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